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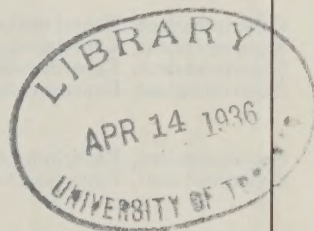
DOMINION OF CANADA, DEPARTMENT OF AGRICULTURE

HYBRIDIZATION
OF DOMESTIC CATTLE, BISON
AND YAK

REPORT OF THE WAINWRIGHT EXPERIMENT

ALAN DEAKIN AND G. W. MUIR
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HYBRIDIZATION OF DOMESTIC CATTLE, BISON AND YAK

ALAN DEAKIN, G. W. MUIR AND A. G. SMITH

INTRODUCTION

Several cattle breeders in North America have at different times undertaken the crossing of American buffalo or bison (*Bison americanus*) with domestic cattle (*Bos taurus*). Varying degrees of success have attended the attempts of these breeders, and some of them succeeded in developing herds of hybrid animals, called cattalo, but none of the herds, however, have reached the stage of established economic importance. Considerable patience and capital expenditure is needed to establish a hybrid herd, owing to the heavy mortality of both cows and calves at the time of parturition, sterility of male hybrids, mating indifference, diseases and accidental deaths. The hybrids, however, inherit the thrifty and hardy characteristics of the bison together with a good measure of the superior beef conformation of domestic cattle. They, therefore, offer possibilities for economical beef production in the vast areas of the northern sections of the Prairie Provinces. Consequently, the Experimental Farms Branch took the opportunity of purchasing some hybrid animals from the Mossom Boyd herd in 1916. At that time Dr. E. S. Archibald was Dominion Animal Husbandman and directed the experiment. Later Mr. G. B. Rothwell succeeded to this position and was in charge of the experiment until 1931. The hybrid animals were finally located at Buffalo Park, Wainwright, Alberta, through the courtesy and co-operation of the Parks Branch, Department of the Interior. The Health of Animals Branch also kindly co-operated by supplying officers for the veterinary inspection of the animals. In 1919 a few yak (*Bibos grunniens*) were added to the herd and used for cross-breeding purposes.

Literature

There is very little scientific literature on the hybridization of bison and domestic cattle. In 1917 Garretson (8) published a paper giving a brief history of hybridization experiments in America, the material for which appears to have been largely obtained through correspondence. According to this author the earliest account of hybrid animals is given in Peter Kalm's "Travels in North America," in which the author states that in 1750 the calves of wild cows and oxen were to be met with in Carolina and other provinces south of Pennsylvania. Another author, Gallatin, is quoted as saying that "the mixed breed was quite common in 1784 in some of the northern counties of Virginia and the cows, the issue of the mixture, propagated like all others."

During the latter part of the last century several breeders who had preserved small herds of bison, or had the opportunity to purchase some, became earnestly interested in the hybridization of bison and cattle. Many of these breeders had observed the thrifty and hardy characteristics of the bison and conceived the idea of incorporating them in their range cattle. Thus, C. J. Jones (15) of

¹ Respectively, Geneticist and Dominion Animal Husbandman, Animal Husbandry Division, Experimental Farms Branch, Department of Agriculture, and Superintendent, Buffalo Park, Wainwright, Alberta, Department of the Interior.

Kansas states that he lost 75 per cent of his cattle during a storm in 1885, while all the bison survived. According to Garretson, prominent among the men who made successful experiments were: Col. C. Goodnight, Goodnight, Texas; Major S. I. Bedsen, Winnipeg Manitoba; Col. C. J. Jones, (Buffalo Jones), Garden City, Kansas; J. E. Dooley, Salt Lake City, Utah; J. Philip, Fort Pierre, South Dakota; and M. M. Boyd, Bobcaygeon, Ontario.

Most of these breeders experienced a high mortality of both cows and calves as a result of crossing. C. J. Jones (8) claims to have lost 30 cows and obtained only 4 calves as a result of breeding 80 or 90 cows to 6 bison bulls in 1888. He claimed that his subsequent losses were much less due to the more careful selection of cows. In a letter dated November 12, 1923, Col. Goodnight maintains that through the proper choice of cows (mature, roomy cows) a 10 per cent calf crop can be expected.

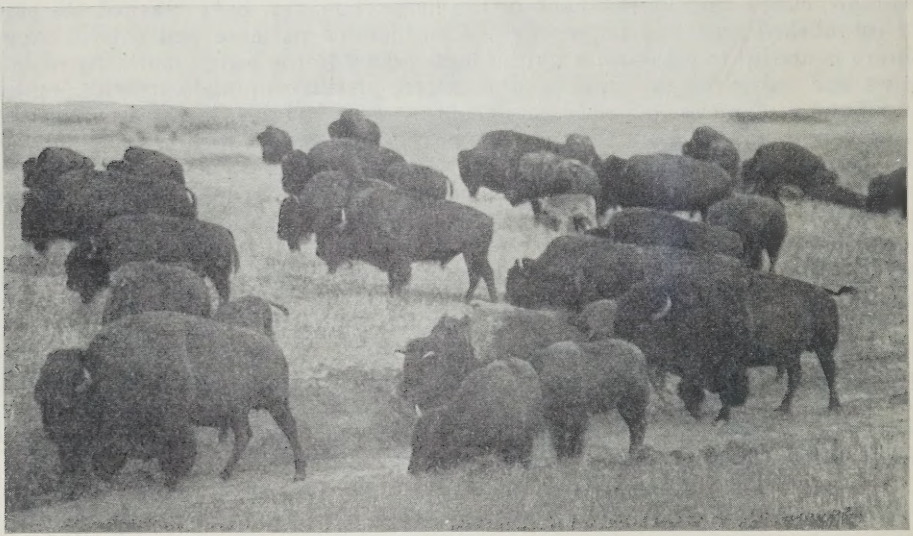


FIG. 1.—A group of bison in the Buffalo National Park. (Photo by Carsell, Wainwright.)

Difficulties were experienced in getting the bison and domestic to mate. One way of circumventing this obstacle was that of raising bison calves on domestic cows, a practice which assured their mating when mature. The reverse cross, domestic males and bison females, does not seem to have been practised to any extent, except in later years, probably because of the scarcity of bison females, mating indifference and the extra trouble. There appears to be an idea also that the cross could not be accomplished. Most of the more common beef breeds have been used for crossing, though probably the Aberdeen-Angus and Herefords have been the most popular. There is some correspondence to the effect that a few breeders have used Brahman cattle (*Bos indicus*) for crossing with bison.

The hybridization of the yak and domestic cattle is quite common in some Asiatic countries (10, 16, 25) and apparently little trouble is experienced with mating or calving.

Names of Hybrids

The hybrids from bison and domestic cattle were apparently first given a distinctive name by Col. C. J. Jones (Buffalo Jones) of Kansas in 1888, (8). Jones coined the word "catalo" from the first three letters of cattle and the

last three of buffalo. The name has come to be more frequently spelled, however, with two "t's". A letter on file from C. J. Jones dated July 14, 1917, reads in part:—

"I desire to say it is hardly fair to the buffalo to give the cattle a preponderance in even the name. If it is desirable to distinguish the predominating blood, why not, where it is in favour of the cattle spell it 'cattalo' but where it runs in favour of buffalo 'catfalo.' But the word 'catalo' indicates the animal to be neither cattle nor buffalo, but a hybrid."

On the other hand, Mossom Boyd (4) used the word "cattalo" (spelling it with two "t's") for the progeny of two hybrids and, Goodnight (11) spells the word "cattalow" and used the name for all hybrids.

In Asiatic countries, according to Lisbre (18) the yak-domestic hybrids are given distinctive names both according to the sex and kind of cross. Thus, in domestic male X yak female crosses, the hybrid male is called "*dzo*" and the female hybrid a "*dzomo*," while in the reciprocal crosses, domestic female X yak male, the hybrid male is called a "*podzo*" and the hybrid female a "*tedzo*." This terminology has not been applied to the Wainwright yak hybrids nor has any other distinctive name been given them.



FIG. 2.—A trio of yak—two bulls and a cow—in the Buffalo National Park.

Wainwright Herd

In 1894 the Mossom Boyd Company (3) of Bobcaygeon, Ontario, commenced the crossing of bison males with various breeds of domestic females. By 1916 a very fine herd of hybrids had been developed including two hybrid males proven to be fertile. Since the herd was to be dispersed, the Dominion Experimental Farms Branch made a selection of 16 females and 4 males. This hybrid herd was made up of the following: Four first cross hybrid cows (50 per cent bison) and proven breeders; four second-cross cows (75 per cent bison) and proven breeders; one second-cross cow (25 per cent bison); seven cattalo cows and heifers (25 to 50 per cent bison); and four hybrid bulls (31 to 75 per cent bison), one of which was a proven breeder.

The herd was first located at the Dominion Experimental Farm, Scott, Saskatchewan. Through the co-operation of the Parks Branch, Department of the Interior, arrangements were made to have some of the area in Buffalo Park, Wainwright, Alberta, reserved for the hybrids, and in 1919 they were moved to that location. To the original hybrid herd a few domestic cattle were added from time to time, including registered or high-grade Aberdeen-Angus, Shorthorns, Herefords, and Holstein-Friesians.

In 1919 a bison male calf was obtained from the bison herd, raised on a domestic cow and mated in the breeding season of 1921, with hybrid and domestic females. Since that time other bison males and females have been added to the hybrid herd. The females are isolated from the bison herd, as calves, during the bison round-ups which occur mostly in November.

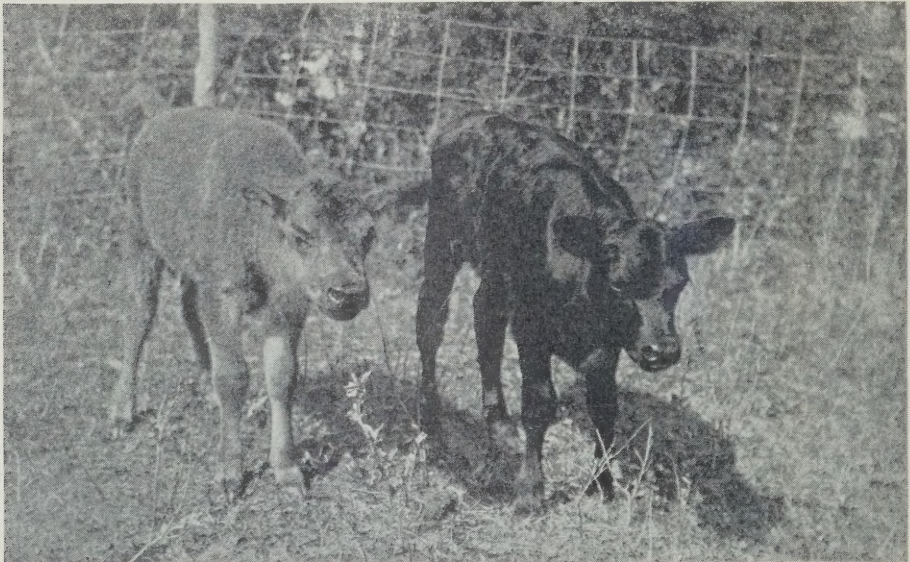


FIG. 3.—Left, a bison calf; right, an Angus calf.

In 1921, a few yak were included in the hybridization experiment. It is generally considered that the yak occupies zoologically, an intermediate position between the bison and domestic cattle. It was, therefore, thought the yak might aid in the obtaining of fertile hybrid males. The yak was introduced (2) into Canada in 1909 as a gift of the Duke of Bedford to the Dominion Government. The herd consisted of one aged bull, one yearling bull, two aged cows, and two yearling heifers, and was first located at the Dominion Experimental Farm, Brandon, Manitoba. In the spring of 1910, the aged bull and one aged cow died as a result of digestive disturbances. Since the herd did not reproduce during the next two years, it was removed to a more natural environment of higher altitudes, namely, Rocky Mountain Park, Banff, Alberta, and placed under the jurisdiction of the Parks Branch. Here the yak began to breed regularly and in 1919 most of them were transferred to Buffalo Park, Wainwright.

The origin and establishment of Canada's national buffalo herd is described in a pamphlet (1) published by the National Parks Branch, Department of the Interior.

Management

Buffalo Park, Wainwright, where the main herd of buffalo is kept, has a sandy loam soil of rolling topography with numerous bluffs of mostly small poplar and willow trees and is well supplied with small to medium sized lakes (or sloughs) some of which are alkaline. The temperature in July, the warmest month, may range from over 90° F. to a few degrees above freezing, averaging between 60 and 70° F. In January, usually the coldest month, the temperature occasionally drops lower than -40° F. and it may fluctuate as much as 80 degrees during the month. The annual precipitation varies considerably, averaging about fifteen inches, about one-sixth of which falls as snow.

The hybrid herd is ranged in a series of six enclosures which vary in size from twenty to a few hundred acres. Owing to the bluffs in the enclosures, animals that slink off by themselves are frequently lost for several days. A strongly built corral with a squeeze chute is centrally located and serves for separating, examining and tagging of the animals. Two or three mounted herders are necessary to corral the animals and sometimes it is impossible to get them all in the corrals.

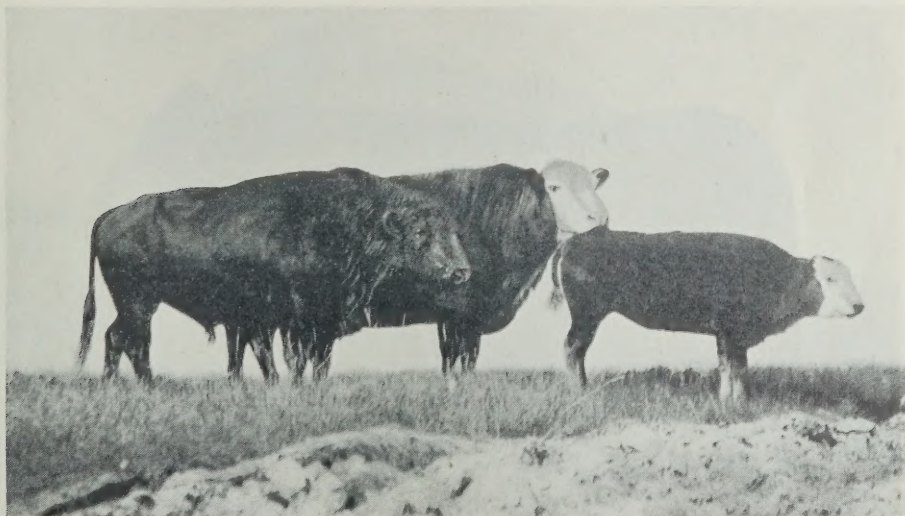


FIG. 4.—A half bison hybrid male (domestic sire), and a half bison hybrid brindle female (bison sire, Hereford dam) and her calf (three-fourths bison) by a bison bull. (Photo by Carsell.)

Breeding groups are segregated and mated towards the end of July, about the time of the commencement of the bison running season. As occasion demands, veterinary examination of the animals is arranged. In summer, the enclosures are regularly patrolled by a mounted herdsman who lives on the premises. In winter, late December to April, the calves and domestic cows in calf, are put into winter quarters, which consist of corrals and sheds, and fed hay and straw. Animals in the enclosures are fed hay and straw during stormy weather.

Records

The hybridization experiment was initiated on the practical basis of testing out hybrids for economy of meat production under severe and semi-domesticated conditions. The records kept consist of a daily diary kept by the herdsman in which observed services, calvings, abortions, deaths, etc., are recorded.

Progeny cards are made out for each female when it gives birth to its first calf, other than the pure bison and yak females. The hybrid animals are known by their date of birth, hybridity and colour or other characteristics. An abbreviated form of their hybridity, the sire being noted first, appears on their metal ear-tags. Domestic cattle are known by their breed, while an ear-tag number identifies the pure-bred animals and some individuals characteristics that of the grade animals. Bison and yak are not known individually. The hybrid calves are doubly ear-tagged at weaning time, the tags being later replaced if necessary. Mating lists, consisting of the various groupings of male and females, are made up annually.

Progress reports of the experiment have appeared from time to time (12, 23). In the present bulletin the entire data obtained up to January, 1935, are presented together with later information on the sterility of hybrid bulls. The breeding records given are from our original crosses, as none of the hybrids obtained from the Boyd herd reproduced. The data for the most part are fragmentary; however, it was felt that as complete an analysis of the results as could reasonably be made, together with the observations of other hybridizers, would not be out of place.



FIG. 5.—A yak sire, Angus dam, female hybrid. Note the heavy build, yak-like back and tail, poor coupling and Angus type fore end. (Photo by Carsell, Wainwright.)

Coat Colour Inheritance

Bison calves at birth have a uniformly yellowish brown coat, and black noses. Towards autumn the coat colour gradually changes to a darkish brown, a colour which characterizes the older animals. There is a seasonal change in the shade of colour of adult animals. In November and December, the coat is dark coloured but towards spring, as it begins to shed, it grows paler. The long, dark, almost black hairs of the head and forelegs, however, are retained throughout the year. The coats of older animals are usually a little lighter in shade than those of younger ones. The yak calves are of a brownish black colour; the under coat of older animals is black and the outer has a brownish tinge, especially pronounced in the spring. The yak has a characteristic grey nose, the hair being very short and grey coloured around the muzzle with a mixture of grey and black hairs on the nose; the skin of the muzzle is black.

Descriptions of the coat colour of hybrids are very difficult because of individual variability in coat pattern and shades. It is probable, also, that hair length is one factor in determining different shades. In the following passages the data obtained from the combinations of domestic, bison and yak crosses are given. For the most part, colour descriptions are obtained on yearlings during the summer, although those of a few younger hybrids are included.

Angus sire X bison dams gave 5 blacks, 3 dark browns, and 4 brindles of light to dark shade.

Angus sire X half domestic and half bison dams gave 4 blacks, 1 dark brown, and 1 fawn from Shorthorn hybrids; 1 black with white face from a Hereford hybrid; and 1 black from an Angus hybrid.

Angus sire X three-fourths domestic, one-fourth bison dams gave 2 blacks.

Angus sire X yak dams gave 2 blacks.



FIG. 6.—A yak sire, bison dam, hybrid (dehorned). Note the yak type of conformation, grey nose, muzzle, fringe and tail. A very fleet animal. (Photo by Carsell, Wainwright.)

Angus sire X half domestic, half yak dams gave 8 all blacks. The dams were 2 hybrid Herefords, 4 hybrid Angus, and 2 hybrid Shorthorns.

Angus sire X half yak, half bison dams gave 1 brown with grey nose and 1 brownish black.

Bison sire X domestic dams gave 2 dark brindled and 1 brown from 3 Shorthorns; 1 brownish black from a Holstein; and 1 light brindled with white face from a Hereford.

Bison sire X bison-Hereford hybrid dam gave a light brindle with a white face.

Bison sire X yak-Angus hybrid dam gave 1 black.

Yak sire X domestic dams gave 6 black from 4 Angus and 2 Shorthorn dams, and 1 dark brindled with white face, breast and udder, and 1 brindled with 2 white hind feet and star from 2 Hereford dams.

Yak sire X bison dam gave 1 dark brown with a grey nose.

Yak sire X half domestic, half yak dams gave 1 dark brown, faintly brindled with a grey nose, white hind feet and star, from a Shorthorn hybrid.

Yak sire X half domestic, half bison dams gave 1 black with a white face from a Hereford hybrid and 1 black with a grey nose from a Shorthorn hybrid.

The colour descriptions given by Boyd (4) for 28 hybrids from a bison male X domestic cows are as follows: 3 pure Hereford dams gave 2 blacks and 1 brindled, with white faces, 1 of which had a little white on the underline; 3 pure and 8 grade Angus, 2 grade Galloway, and 1 grade Ayrshire, and 3 red scrubs with white spots, gave 17 black hybrids. The hybrid from the grade Ayrshire had a small white spot on its back. One pure Sussex (red), 1 grade Holstein, and 4 red scrubs with white spots, 1 red and 1 black scrub, gave 8 brindled hybrids.

There are a few deductions on colour inheritance which can be drawn from the above data. The first-cross bison-domestic hybrids described as black are not pure black, but have a rich brownish tinge, as observed also by Boyd (3). A bison-grade Durham hybrid purchased from Boyd, however, was described as coal black. A limiting factor in coat colour analysis is the number of grade animals used and, also, an absence of certainty that the pure-bred animals used were homozygous for their colour patterns.

It is reasonable to suppose that yak and particularly bison, have some modifying factors different from those found in domestic cattle, and that the colour factors may behave differently in species crosses. However, it is the object to present the principal colour factors of these two species in relationship to domestic cattle. The proposed colour formulae are:—

Bison bb BsBs brbr SS DD ii inin

Yak BB bsbs brbr SS dd ii inin gg

The bison formula is similar to that given by Ibsen (13) for dark Jerseys except for the incompletely dominant dilution factors (DD) while the yak formula approximates that of the Angus, one exception being grey nose (gg).

That bison are recessive for black (bb) and dominant for black spotting (BsBs) is indicated by the fact that bison calves are lighter coloured at birth than later in life. A test cross would be the mating of non-black, domestic X bison hybrids to a non-black domestic. Among the hybrids purchased from Boyd there was one such animal, the domestics being Herefords, and the hybrid had a Hereford pattern. In addition, two other animals, the progeny of domestic-bison hybrids, which had no evidence of their having any Angus in their ancestry, were described as of bison colour and dark brindle respectively. That the bison are self or solid coloured (SS) is indicated, experimentally, from the bison-Holstein hybrid, which has a solid brownish-black colour. The yak are also selfs, and the yak-domestic hybrids are solid-coloured except Hereford hybrids.

With regard to dilution factors, the data fit the hypothesis that the bison has the incompletely dominant factors (DD), probably similar to that found in West Highland cattle by Wilson (27) and described as dun, though the colour as given in a colour plate does not quite correspond to bison colour. Watson (26) considers the dun of Highland cattle to be caused by colour factors and not dilution factors as suggested by Wilson and later by Wright (30). In addition, it would appear that bison as well as yak are recessive for intense colour (ii), a factor which, in black animals, is responsible for a brownish tinge, although Ibsen considers that the non-intensity factors have little effect upon the Angus.

On the above hypothesis the blacks (brownish blacks) from the bison-Angus cross would be Bb Dd Ii, and the browns Bb Dd ii, the latter being similar to the yak-bison hybrid. In addition to these two colours there are also some

brindles among the bison-Angus and other bison-domestic crosses and yak-Hereford crosses. Cole (5) states that the brindling factor (Br) may be carried in blacks but is masked by the B factor, and also in reds, but requires a partial extension factor (Bs) for its expression. On this hypothesis the brindles from the bison-domestic crosses would be $bb\ Bsbs\ Brbr$. This would require that the Angus be heterozygous for both brindling and black. That at least one Angus was heterozygous for black (Bb) is indicated from the appearance of a fawn coloured hybrid (probably a $bb\ bsbs\ Dd\ ii\ Ss$, that is, a dilute red) from an Angus sire and bison-Shorthorn dam. This does not explain, however, the brindles from the yak-Hereford crosses, as it is extremely unlikely that any of the yak are heterozygous for black. It is, therefore, likely that at least heterozygous blacks (Bb) may show brindling when the Br factor is present, providing the black colour is sufficiently diluted by modifying factors, such as dilution (D), non-intensity (ii), and the Hereford pattern S^h (or dilution factors associated with it) and probably others, and that the different combinations of these give from dark to light brindles. On this hypothesis it would seem that the brindling factor acts as a local intensifier of black pigment and causes the striped or brindle pattern.



FIG. 7.—A three-fourths yak, one-fourth Shorthorn. Note the white hind feet and star, but otherwise generally yak type.

The Hereford pattern (S^hS^h) is considered by Ibsen (13) to be allelomorphous to S and s and incompletely dominant to self (S) and completely to recessive white spotting (s). A little white colour, other than on the face, is present in some of the bison-Hereford and yak-Hereford hybrids. There is an indication that the yak have a modifying factor for white face. Neither yak nor bison appear to have the dominant inguinal white factor (InIn) found in some Angus; this characteristic does appear in many of the Angus hybrids.

The grey nose (gg) present in yak is probably peculiar to that species.* In the yak-Angus hybrids it is recessive, but dominant in the yak-bison hybrid. Also an Angus sire, yak-bison hybrid, had a grey nose. This suggests that the

* In Guernsey and Jersey cattle the whitish or yellowish circle of hairs around the muzzle when present, is usually sharply defined.

grey nose factor is dominant in the presence of a dominant dilution factor. Usually fewer grey hairs appear on the noses of the hybrids possessing the characteristic.

Hair Characteristics

The bison male in his prime has a heavy, curly crop of long hair covering his forequarters and back. In addition, long hairs are present on the top of the head, a tuft of long hairs on the under side of the jaw, a long fringe on the under side of the neck and brisket and a tuft on each of the forelegs, called chaps. The female bison is proportionately similar. The hair characteristics of the bison-domestic hybrids are similar to those of pure domestic cattle, except that the hair of bison-domestic hybrids is a little thicker and longer. Occasionally, however, the hybrids have a very thin fringe on the under sides of the body and on the throat, the latter being occasionally seen in pure domestics. Whether the dominance of the domestic type coat is on a single or multiple factor basis is not known, as there are not sufficient bison-hybrid crosses to determine this point. One such three-fourths bison hybrid was of domestic type but had a tuft of hair on the jaw. The hair length of domestic cattle is very variable and considerably influenced by season and environment. Boyd (4) observed an increase in quality and hair length in hybrids, and one of his objectives was to obtain hybrids with the superior coat of the bison. For purposes of robes and coats the bison hides are much more valuable than those of the hybrids.

The yak coat is characterized by long hairs in the tail, fairly long hairs on the head, and a skirt or fringe of long hairs on the legs and either side of the body, commencing at a level with the elbow and reaching almost to the ground. The hair is shed in the spring, falling off in patches in a similar manner to that of the bison.

In a yak-bison cross the hybrid had a yak-type coat, but the skirt hairs were not so long as in the pure yak, and the hair was straight rather than crimped as in the yak. In the yak-domestic hybrids the domestic-type coat is in some cases dominant with the exception of some longer hairs on the thigh, and long hairs on the tail. In other cases the hybrids have a thin fringe of hair on the throat and fairly large fringes on the under sides of the body. Two reciprocal hybrids were identical in this respect. One yak X yak-domestic hybrid had a yak type coat although the hairs of the skirt were shorter. From the crossing of Zebu and yak, Zawadosky (31) considers the yak-type coat to be on a monofactorial basis but incompletely dominant. This hypothesis would seem to be the best fit for the yak, while in the domestic-bison cross the domestic-type coat has a greater degree of dominance. The symbols hlhl (hair length) are, therefore, proposed.

Tail Characteristics

The tails of bison are comparatively short, being about eighteen inches in length, although they vary a little, but probably rarely exceed two feet. The yak have a characteristic horse-like tail, the long hairs extending from near the root of the tail to below the hocks. The yak-type tail is almost completely dominant to both that of the bison and of domestic cattle. The long hairs of the tail of first-cross hybrids do not, as a rule, begin so near the root of the tail as in yak and, in addition, the tail is less bushy. The tails of three-fourths domestic one-fourth yak are variable, some being almost as bushy as those of the first-cross hybrids and others no more bushy than those of domestic cattle. The yak-type tail is, therefore, incompletely dominant and would appear to be principally controlled by a single factor. Zawadowsky (31) considers the yak tail to be incompletely dominant and modified by the hair length factor. He used the symbols "CC" but since these are generally used for the colour factor it is proposed to use the symbols "TT."

The tail length of the bison-domestic crosses is about intermediate, though sometimes nearer to that of domestic cattle. The three-fourths domestic one-fourth bison hybrids have domestic-like tails. It is, therefore, of a blending type of inheritance but probably controlled by more than one factor.

Horns

As a safety measure it has been the practice to dehorn all animals. Consequently, the data on the mode of inheritance of horn characteristics are meagre. The hybrid calves from domestic females are dehorned by use of a caustic, others, including pure bison, are dehorned as yearlings. Bison horns are shaped outwards and upwards and then inwards with advancing years. Yak horns are similarly shaped though variable. Some animals have wide spreading horns, others more of the Ayrshire type, while a few in the Wainwright herd are polled. A bison-Shorthorn and yak-Shorthorn had bison-type horns. Crosses between Aberdeen Angus (polled) and bison and yak gave all polled hybrids, though a few of the males had well-developed scurs which are frequently loose and get broken off. The same is true of the males of Angus-hybrid crosses. The horned-polled condition (hh HH) is thus inherited, as in domestic breeds.

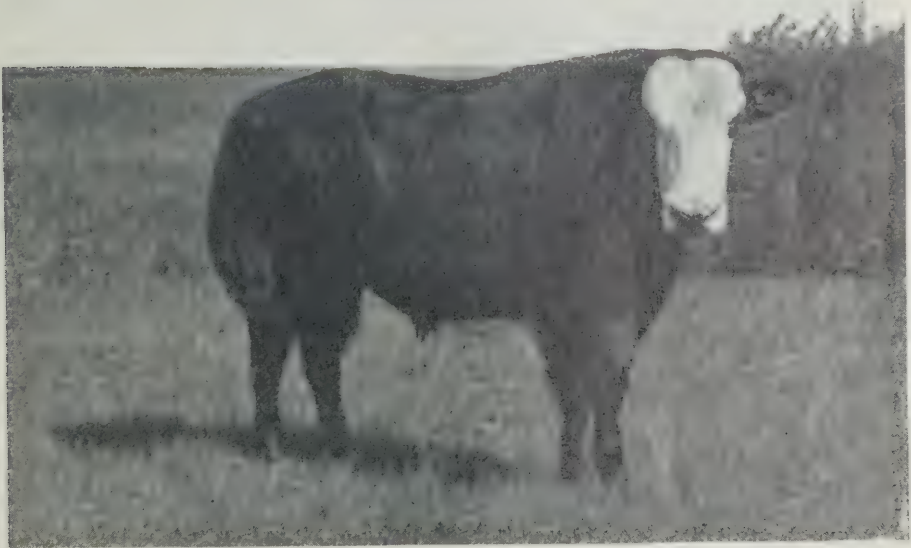


FIG. 8.—A half yak, one-fourth bison, one-fourth Hereford. Note the yak type of back, tail and muzzle.

Voice

The bison have a characteristic low, abrupt grunt which is used particularly by the males during the running season, and by females for calling their calves, and by both when disturbed or lost. Domestic calves when foster-mothered by bison, are at first afraid of the grunt, but later become accustomed to it. The voice characteristic is a definitely inherited trait. Boyd (4) gives the bison voice as dominant but our experience indicates that of incomplete dominance. The bison-domestic hybrid females grunt, though the grunt can be somewhat prolonged. Some hybrid males can fairly closely imitate the bellow and low of domestic males. Some of the one-fourth bison hybrids are known to bellow and low similarly to domestic bulls, while a three-fourths bison female grunts

like a pure bison. There is thus an indication that the bison grunt is controlled by one pair of factors (VV) which exhibit incomplete dominance in the female with a further modification towards the domestic-type voice in the male. The yak voice is similar to that of the bison and the trait is inherited similarly. A bison-yak hybrid had a similar voice to that of both parents. In yak-Schwyz hybrids, Gitz (10) describes the voice as being intermediate between the yak's grunt and the low of cattle.

Muzzle

The muzzles of cattle, bison and yak differ in structure. The bison have a peculiar "flatness" to the muzzle as compared with the more round type of that of cattle, the latter type being dominant. The yak muzzle is different in that the grooves of the nostrils closely approach each other, and at a broad angle, which gives a lip-like appearance to the muzzle above the nostrils. The domestic type is incompletely dominant, as was found also in the zebu-yak crosses (31), to that of the yak. The three-fourths yak one-fourth bison hybrids have nostrils which vary from about the pure yak type to the intermediate type. It is probable, therefore, that it may be of the single factor type or principally so (N_sN_s).

Wallowing

Bison have the habit of pawing up the ground and making shallow holes in which to wallow for relief from flies and to help the shedding of hair in the spring. Rubbing posts, or large stones and trees are also used for this purpose. Since the hybrids do not shed their hair in the same manner as bison, and since they have longer tails, they have less need for wallow holes. Nevertheless, some of the first-cross hybrids do tend to wallow a little. The habit of wallowing is not possessed by the yak.

Rising

It has been stated (11) that bison rise on their fore feet first, like a horse, and not like cattle. When startled, bison appear to bounce up on all fours almost instantaneously, from which, no doubt, the impression that they rise on their fore feet first was founded. When they rise leisurely, however, they do so by getting on their hind feet first, similarly to cattle.

Hides

The hides of bison are very pliant and elastic and make excellent robes and coats when the hair is left on. Leather made from bison hides, however, while very useful for army accoutrements, is not suitable for harness, belting, or the shoe trade (except moccasins) because of its pliancy and porosity (9). Several suitable hides from bison-domestic hybrids have been tanned for fur; none have been tanned for leather. No doubt the three-fourths domestics hybrid hides are similar in quality to those of domestic cattle. No comparisons of yak and yak-hybrid hides have been made at Wainwright; the latter, however, are reputed to be (25) not inferior to those of cattle.

Hybrid Vigour

The bison-domestic crosses show remarkable vigour, which is expressed in size, stamina, and longevity. The stamina and longevity of the bison are characteristic of that species. Two bison cows in the Goodnight herd (9) had calves when over 28 years of age. Three of the Boyd hybrid cows were over 20 years old when slaughtered. The hazards of parturition as well as accidental deaths and infections, however, take their toll of the hybrids. While the hybrids

are usually of a docile nature, they show remarkable speed and stamina when disturbed. When they once break away it is difficult and sometimes impossible to corral them. They will run hard for an hour or so and then sulk and charge the mounted rider if disturbed. The yak-domestic hybrids, while they have greater weight and size, do not have the same degree of stamina and speed as have the bison-domestic hybrids. A yak-bison hybrid has both stamina and speed to a remarkable degree.



FIG. 9.—A three-fourths Angus, one-fourth yak yearling. Note the intermediate yak type tail, but otherwise generally domestic type.

Conformation

The bison is characterized by a massive head carried relatively low, a large hump and relatively small hind quarters. The hump is caused by a relatively greater increase in length of the spinous processes from the lumbar to the cervical regions than is found in domestic cattle. Boyd (3) found the length of the second and third spines of one of his smallest bison bulls to be sixteen and one-half inches, as measured from the centre of the spinal cord. In conformation, the bison-domestic hybrids are about intermediate, being a little nearer to the domestic than to the bison type. Both in size and carriage of the head, the first-cross hybrids are of almost the domestic type, while the hump is much reduced and there is much greater development of the hind quarters and greater breadth than in the bison. The three-fourths domestic one-fourth bison hybrids show some variation in their conformation, but are generally about intermediate between the first-cross hybrid and domestic. A third-cross of domestics (seven-eighths domestic) gives progeny scarcely distinguishable from pure domestic cattle. The three-fourths bison one-fourth domestic hybrids show a predominance of the bison conformation. Generally speaking the hybrid males are smaller and of poorer conformation than the hybrid females, and have a steerish appearance though active sexually.

The yak are characterized by relatively large heads, small humps, swayed backs and fairly small hind quarters. The yak conformation is largely dominant in crosses with both bison and domestic. The yak-domestic cross gives a low-set,

heavy-bodied, solid looking individual, with a very poor blending or coupling of the quarters. Generally speaking, the head and fore quarters are more of the domestic type and the hind quarters more of the yak type, although larger. In the three-fourths domestic one-fourth yak hybrids the domestic traits predominate, and they are thus fairly good beef animals. The yak-bison cross resulted in a fine specimen of a wild animal, being very fleet and agile and much less cumbersome in appearance than the bison, owing to a predominance of the yak type of conformation.

Number of Ribs

The bison are reputed to have fourteen pairs of ribs, while domestic cattle usually have only thirteen pairs although sometimes fourteen pairs are present (24). A few observations on the hybrids have been made with respect to rib number. Of four first-cross bison-domestic hybrids, two had thirteen pairs; a second, fourteen pairs; and a third, thirteen on one side and fourteen on the other. Of three-fourths domestic one-fourth bison hybrids, one had thirteen pairs and two had fourteen pairs. A seven-eighths domestic one-eighth bison hybrid had thirteen pairs. Boyd (4) examined the carcasses of eight or ten hybrids and found only one calf with fourteen pairs of ribs.

Meat

The meat of bison is a little darker in colour and coarser in the grain than is that of domestic cattle. The meat of bison-domestic hybrids in appearance is about intermediate in both colour and grain, and favourable comments have been received on its flavour. Boyd (4) considers the choicest cuts to be on the hump, which, owing to the increased length of the spines, is of greater depth than in domestic cattle. Indeed, one of Boyd's objectives was to increase the size of the hump of his cattalo. The meat of yak is reputed to be of finer grain than that of domestic cattle, but otherwise similar.

Weights

The dressed weights of a few yak, bison and domestic hybrids and bison-domestic hybrid bulls have been obtained, and are presented in the accompanying tables, together with the dressed weights of bison, for comparative purposes. It may be noted that the difference in dressed weights between the sexes of bison is very pronounced, being over 50 per cent for animals four and one-half years and over. The dressing per cent of bison is, of course, very low, due to their enormous heads and heavy hides, the latter often weighing from 150 to 200 pounds. In domestic cattle and yak, sex differences in weight are much less pronounced than in bison, while the hybrid males are generally smaller than the hybrid females.

Breeding Results, Bison

The results from bison-domestic crosses are given in table IV. The 62 pregnancies resulted in 19 male and 17 female live calves, or 58 per cent. There were 20 cows that died as a result of pregnancy and 14 still births, or 22·6 per cent, and 12 abortions or 19·4 per cent of the total. Not all of the calves born alive were raised. A few died as calves or yearlings, mostly as a result of accidents.

The mortality of cows and calves shows striking differences, depending upon which way the cross was made. Of the 15 pregnancies of the domestic sire, bison

TABLE 1.—AVERAGE DRESSED WEIGHTS OF HYBRIDS OF BOTH SEXES FROM YAK, BISON AND DOMESTIC PARENTS

Age	Number of animals	Average weight
years		lb.
$\frac{1}{2}$	2	279
$1\frac{1}{2}$	3	338
$2\frac{1}{2}$	3	550
$3\frac{1}{2}$	5	676
$4\frac{1}{2}$	4	703
$5\frac{1}{2}$	2	702
$6\frac{1}{2}$	1	917

TABLE 2.—AVERAGE DRESSED WEIGHT OF BISON, FROM THE BUFFALO PARK KILL, 1934

Age in years	Males		Females	
	Number	Average weight	Number	Average weight
		lb.		lb.
$2\frac{1}{2}$	496	430		
$3\frac{1}{2}$	146	548	197	444
$4\frac{1}{2}$ to 15.....	375	723	606	465
Aged.....	75	798	9	440

TABLE 3.—DRESSED WEIGHTS OF BISON-DOMESTIC HYBRID MALES

Age	Hybridity	Weight
years		lb.
$2\frac{1}{2}$	Half domestic, half bison.....	627
$5\frac{1}{2}$	Half domestic, half bison.....	840
$6\frac{1}{2}$	Seven-eighths domestic, one-eighth bison.....	650
$6\frac{1}{2}$	Three-fourths domestic, one-fourth bison.....	800
$7\frac{1}{2}$	Three-fourths domestic, one-fourth bison.....	875

dam cross, 14 calves were born alive, there was one still birth, and none of the buffalo dams died, while in the reverse cross, of 26 pregnancies, only 6 calves were born alive, there were 9 still births and 11 abortions, and 16 cows were lost. Similar differences occur in the domestic sire, hybrid dam crosses compared with the bison sire, hybrid dam crosses, but the numbers are smaller. There is, of course, a possibility that abortions among bison dams would pass unnoticed. Moreover, the inspector in charge of the Wainwright bison kill has reported several cases of skeletal bones being found in the uteri of bison cows, and suggested that fetuses are absorbed rather than aborted in this species.

A large mortality of cows has been the common experience of hybridizers (8) although the percentage of losses has varied, and some were so disillusioned with their losses of cows that they gave up the experiment. Owing to the convenience, most hybridizers have used bison males exclusively, and not the reverse cross. Some have suggested that only big, roomy, mature cows should be used, as heifers and compact cows are invariably lost.

The length of the gestation period is probably comparable with that of cattle. Thus, Boyd (3) found normal, first-cross hybrid calves to be carried an average of 264 days and aborted calves 178 days. In the Wainwright herd many of the still births were caused by the size of the calf, and in two cases the cows were killed in an unsuccessful attempt to save the calves by surgically removing them. At birth the hybrid calves from the bison sire-domestic cross are usually larger than domestic calves, while the calves from the domestic sire-bison cross are

comparatively small, similar to pure bison calves. It has been supposed that male hybrids offer calving difficulties because of their hump. The hump of both hybrid and bison calves, however, does not begin to appear until the calves are at least two months of age, and then only a very gradual development occurs.

TABLE 4.—BREEDING RESULTS FROM BISON-DOMESTIC CROSSES

Sire	Dam	Abor- tions	Still births	Cows that died	Live calves	
					Males	Females
Domestic.....	Bison.....		1		7	7
Domestic.....	Half bison, half domestic.....	1		1	7	3
Domestic.....	One-fourth bison, three-fourths domestic.....				1	1
Bison.....	Domestic.....	11	9	16	2	4
Bison.....	One-half bison, one-half domestic.....		3	2	1	1
Bison.....	Three-fourths bison, one-fourth domestic.....		1	1	1	1
Total.....		12	14	20	19	17

TABLE 5.—BREEDING RESULTS FROM YAK-BISON-DOMESTIC CROSSES

Sire	Dam	Abor- tions	Still births	Cows that died	Live calves	
					Males	Females
Domestic.....	Yak.....				1	1
Domestic.....	Half yak, half domestic.....	2	1		10	3
Domestic.....	Half yak, half bison.....				2	2
Domestic.....	Half domestic, one-fourth yak, one-fourth bison.....		1		2	
Bison.....	Half yak, half domestic.....	2	1	1		2
Yak.....	Domestic.....	3	2	1	3	8
Yak.....	Bison.....					1
Yak.....	Half yak, half domestic.....			1	1	
Yak.....	Half bison, half domestic.....				2	1
Half yak, half domestic.....	Half yak, half domestic.....		1			
Total.....		7	6	3	21	18

Sex Ratio

The sex ratio of the live calves is seen to be normal. Unfortunately, the sexes of the aborted and still-born calves were recorded in only a few cases. The few cases recorded, however, show approximately an equal number of either sex. Goodnight (11) reports that he did not get any live males in his first crosses, while Boyd only obtained 6 males among 45 hybrids. Both of these breeders used bison males and domestic cows.

Hydramnios

The phenomenon of excessive amounts of aniniotic fluid, or hydramnios, is responsible for the loss of many calves and some cows. Frequently the cows become so weighted down with the fluid that they cannot rise to their feet. When this stage is reached the fluid is discharged and the foetus dies, but may or may not be aborted at that time. The chronic condition is usually reached at about the eighth month of pregnancy, consequently, the mating season has been deferred until about August 1, to ensure fine spring weather at the time when the cows

are likely to become afflicted. The evidence indicates that hydramnios is confined to pregnancies from bison males and that it is not particularly associated with the sex of the calf. This complicates any genetic explanation, although one has been offered by Crew (7) from the results obtained in the Boyd and Goodnight herds. As stated previously, the bison cow may absorb foetuses rather than abort them, which may offer a partial explanation if it be assumed that absorption commences at early stages of abnormal development. However, it is known from the work in experimental embryology (21) that a degree of specific organization is already laid down in the egg prior to fertilization, hence, it may be that the bison factors exhibit dominance over this abnormal foetal character when acting within their own cytoplasm, but are frequently the cause of hydramnios, or abnormal development resulting in it, when introduced by sperms into the eggs of cattle.



FIG. 10.—A half bison half Holstein. Note the body depth, the fringe on the throat and the under side of the body, and the dairy type fineness of bone and thigh.

Breeding Results—Yak

In Table 5 the results of crosses between yak, bison and cattle are given. As can be noted, the yak-domestic crosses are not accompanied with the high mortality found in the bison-domestic crosses. The domestic sire crossed with yak and yak hybrids, gave a greater percentage of normal calvings than the reverse cross, which results are similar to those found in domestic sire-bison female cross. There are only six pregnancies involving the bison, three of which gave live calves. The bison-yak cross would appear to give slightly better results than the bison-domestic cross. It may be noted that one pregnancy, resulting in a still birth, was obtained as the result of mating two yak-domestic hybrids. Both of these hybrids had a yak sire and an Angus dam.

Mating Indifference

As would be expected, there is some indifference on the part of animals of the different species, and hybrids, to freely mate with one another. As a result the percentage of conceptions is low, ranging from nil to 100 per cent. It is

the general practice of hybridizers to raise bison males in association with domestic cattle to increase the later possibilities of the bison males mating with domestics. A certain indifference to mating, however, is shown by the bison bulls, and some of the domestic cows show fear at the approaches of the bison bull. The reverse cross, domestic male and bison females, exhibit even more mating indifference. The practice followed with bison females is to isolate them from the main bison herd when about six months old, and keep them in the cattalo enclosure. Bison females do not breed as yearlings with the occasional exception of a very early calf. The hybrid females breed regularly as yearlings. The domestic male shows more indifference to mating than the bison females. Age is also a factor, since the older bulls show more mating indifference than do younger bulls. The type of bull also seems to be of importance. A rough, aggressive type of range bull that had been raised from calfhood in association with bison females would doubtless mate more freely than the more highly bred, pure-bred type. Another limiting factor is that bison have a definite running season, and the females stay in season 3 or 4 days with the result that domestic males stay with them and serve them several times during this period, thus reducing their breeding efficiency. In the main bison herd the males are kept at a proportion of about one to every two females. In the cross breeding groups 1 to 3 bison males are mated with up to 10 domestic females. In the reverse cross about 10 bison females are mated with one or two domestic bulls. Mating indifference is occasionally exhibited by hybrid females, as they have been seen to refuse the approaches of both bison and domestic males. Conversely, the bison and domestic males have been seen to refuse to serve hybrid females when in season. The hybrid males show little mating indifference with bison, domestic or hybrid females, although few opportunities have been given them with bison females. Very little mating indifference is apparent between yak and domestic cattle.

Sterility

As stated previously no offspring were obtained from the 16 hybrid females purchased from the Mossom Boyd herd, although some of them were mated at different times with cattle, bison, yak and hybrid males. Of the 16 females purchased, 7 had had calves, and one had aborted a calf. From time to time examinations were made of these females by veterinarians and some of them were reported as being in good breeding condition; others were found to have genital disturbances, and others to be in too high condition, owing to the abundance of grass. A few were lost from time to time through accidents and infections, and the remainder were killed in 1928, at which time some of the cows were over twenty years of age. In addition to veterinary examinations, the whole herd was subjected to the tests for tuberculosis and contagious abortion, and the occasional animal reacted and was slaughtered.

Such infertility of hybrid females is very unusual, as most hybridizers have found very little sterility among them. It was, therefore, probably a combination of several environmental factors that caused the trouble. Some infertility among the hybrid females of original crosses at Wainwright has been experienced, the principal causes being infertility or indifference of the males and high condition and advancing age of females.

Similarly, none of the 4 hybrid males purchased from the Boyd herd—Quinto Porto, Huron, Guy, and Port Royal—left any offspring although they were mated with both hybrid and domestic cows, and were occasionally seen to serve some of them. Quinto Porto, a five-eighths bison hybrid was the sire of Huron.

Prior to purchase, Huron, a five-sixteenths, Guy, a three-fourths, and Port Royal, a five-eighths bison, were given a semen test by a veterinarian of the Health of Animals Branch. From the result of services, Huron was found to have a few well-formed spermatozoa, while Port Royal was found to have large numbers of spermatozoa that were actively motile three hours after securing the semen. A testicular puncture was performed on Guy, with the result that a few well formed spermatazoa were found as well as some of irregular shape. After being tried for several years with no success, the bulls were finally disposed of.

Similarly, none of the hybrid males obtained from original crosses at Wainwright has proven to be fertile. Six hybrid males have been tried out by mating with both domestic and hybrid females varying from one to three seasons. These hybrid males include 3 first-cross (half bison), 2 second-cross (one-fourth bison), and 1 third-cross (one-eighth bison).

In the summer of 1934, a few semen tests were made on a few of the hybrid males. Matings were secured from a three-year-old first-cross hybrid and a four-year-old one-quarter bison, and vaginal smears obtained. In addition, 3 other males, 2 first-cross hybrids, a yearling and a five-year-old, respectively, and a yearling one-fourth bison, were put in the squeeze chute and smears obtained through massaging the accessory genital organs per rectum. It has been shown by Miller and Evans (19) that the ampulae of the ductus deferens should be massaged as well as the seminal vesicles in order to obtain spermatozoa. None of the smears obtained contained any spermatozoa. The vaginal smears contained numerous epithelial cells and cell debris, while those obtained from massaging the bulls contained very few.



FIG. 11.—Two yearling males; a brindled half bison half domestic (Shorthorn dam) and a fawn one-fourth bison three-fourths domestic (Angus sire, Shorthorn granddam).

In addition to the semen tests, information on the causes of sterility was obtained from 5 hybrid bulls slaughtered during the bison kill at Wainwright in December, 1934. At that time the hybrid males in the herd consisted of 1 bison male-domestic female yearling hybrid, 5 domestic male-bison female hybrids ranging in age from one and one-half to five and one-half years, 6 three-fourths domestic one-fourth bison hybrids ranging in age from one and one-half

to seven and one-half years, and 1 seven-eighths domestic, one-eighth bison hybrid six and one-half years old. The 5 hybrids slaughtered were a seven and one-half and six and one-half year old, respectively, three-fourths domestic, one-fourth bison; a five and one-half and two and one-half year old half bison, half domestic, and the one-eighth bison, seven-eighths domestic hybrid. With the exception of the two-year-old bison-domestic hybrid, the males had been mated from one to three seasons with a few hybrid and domestic females. Through the courtesy of the Health of Animals Branch, the veterinarian in charge of the kill, Dr. E. E. Carlson, obtained data and information on the dressed weights, number of ribs, disease conditions, appearance of the genitalia and weights of testicles. In addition, small pieces of each testicle were put in a fixative solution for the purpose of sectioning. The dressed weights and number of ribs are given in other sections. Except for a few parasites in some of the carcasses, no diseased condition was found. The genitalia were described as of normal appearance. The seven-eighths domestic, one-eighth bison hybrid was found to have larger seminal vesicles, prostate glands, and testicles than the other hybrids. In addition, the scrotum was found to be more pendulous, with a well-defined neck. The average weight of each testicle was found to be 8 and 9 ounces respectively for the 2 three-fourths domestic, one-quarter bison hybrids, and 8 ounces each for the 2 half domestic, half bison, and thirteen ounces for the seven-eighths, domestic, one-eighth bison. The weight of domestic bulls' testicles is given by Sisson (24) as 8 to 9 ounces each.

In the summer of 1935, seven of the eight remaining hybrid bulls (three half bison and four one-fourth bison, three of the latter having had natural breeding tests for one season) were given more thorough tests by permitting each male to serve a domestic female, then drawing off the vaginal fluid by means of a syringe and examining samples under the microscope. Not a single sperm was observed in any of the samples. A quiet two-year-old one-fourth bison hybrid (fawn coloured) was given an additional test by the use of an artificial vagina (Cambridge model). Two services were secured by this method, resulting in approximately 1 c.c. of seminal fluid per service. The fluid was pale straw coloured rather than the normal milky colour, and was probably largely urine. No sperms were observed in the fluid.

Two animals were slaughtered, a four-year-old half bison and a five-year-old one-fourth bison. The dressed weight of the hybrid was 774 pounds, testes 8 ounces each and seminal vesicles 4 ounces each. The one-fourth hybrid weighed 800 pounds, testes 9 and 10 ounces respectively, and seminal vesicles 2 ounces each. The scrotal pouches of both were short, and had thick skins with a dense covering of short hairs.

Histology of Testes

Microphotographs of sections of the five hybrid males are shown in Plate I. Photographs 1 and 2 are respectively from a seven and one-half and six and one-half year old three-fourths domestic, one-fourth bison hybrid. As can be noted, there is a complete absence of germinal epithelium. The semeniferous tubules are in a degenerative state with no typical arrangement; a marked cytolysis and sloughed off cells and cell debris are present in the lumina of the tubules. The seven and one-half year old shows considerably more interstitial tissue than the other. Photographs three and four are from two first-cross bison-domestic hybrids and are similar to the three-fourths domestic, one-fourth bison,

though the lumina do not contain so much cell debris, especially No. 3, a two and one-half year old hybrid, compared with the five and one-half year old hybrid. Photographs 5 and 6 are respectively a low and high magnification of a section from the seven and one-half year old seven-eighths domestic, one-eighth bison. The semeniferous tubules show varying degrees of degeneration. Indications of active mitosis and a degree of differentiation of spermatids towards spermatozoa are seen in some of the tubules. However, the usual typical arrangement within the tubules is absent. Of the two animals slaughtered in July, 1935, sections of the testes of the first-cross four-year-old hybrid revealed a complete absence of germinal epithelium similar to the half and one-fourth hybrids described above. Sections of the testes of the one-fourth hybrid, however, revealed a histological condition similar to the one-eighth hybrid described above. The germinal epithelium showed active mitosis while a small percentage of spermatids were differentiating towards the formation of spermatozoa. An absence of spermatogenesis and degeneration of semeniferous tubules was found in a yak-zebu male hybrid, by Zawadowsky (31), which had previously been proven sterile by mating tests.

The question naturally arises as to whether spermatogenesis in bison and yak is in abeyance during the winter months, or whether some regression takes place. However, bison calves are born over a period of months and the mating of bison and hybrids has been accomplished during late autumn. It has been the practice, however, to maintain the natural breeding season as far as possible. It would appear doubtful whether actual regression of germinal tissue takes place in bison.

Species Crosses

The most familiar example of sterility of interspecific hybrids is the mule. In this cross both sexes are sterile, although a few fertile females have been reported. According to Wodsedalek (28) the jack has sixty-five chromosomes and the mare thirty-eight, and the sex chromosome mechanism in the horse was found to be of the XO type. Painter (22), however, found sixty to be the chromosome number of the horse, and the sex chromosome mechanism to be the XY type. Owing to the fertility of female hybrids of bison, cattle and yak, it is extremely doubtful if there is any difference in chromosome number between these three species. The chromosome number in cattle is given by Wodsedalek (29) as thirty-eight and of the XO type. It is not likely that any gross sex chromosome difference between cattle and bison is responsible for the sterility as the males are sterile whichever way the cross is made. A possibility, however, is that of physiological incompatibility of the sex chromosomes. Thus, Lancefield (17) found two races of *Drosophila obscura* the reciprocal hybrid males of which were sterile. The chromosome numbers of the two races were the same, but the Y chromosomes differed slightly in both size and shape.

Causes of Sterility

There is evidence which points to the cause of sterility in hybrids as being due to temperature difference within the scrotal pouches of cattle compared with those of bison and yak. It is well known that the testis, or testes of animals that remain in the body cavity, do not produce normal spermatozoa; animals with such are known as cryptorchids. If one testis had descended into the scrotum, however, the animal is normally fertile, as one testis can supply sufficient sperms for fertility. As an explanation, Crew (6) suggested that the higher temperature

of the body compared with that of the scrotum was the cause of undescended testes failing to produce normal sperms. Moore and others (20) have experimentally produced cryptorchids by (a) insulating the scrotum and thus raising the temperature, (b) applying heat to the scrotum, and (c) surgically putting the testicle back into the abdomen. Depending upon the length of treatment, temporary to permanent sterility is obtained. Confinement of the testicle to the abdomen for one week causes the germinal epithelium to lose its typical arrangement, accompanied by marked cytolysis and fragmentation which fill the lumina of the semeniferous tubules with debris. With a three or four-month confinement of the testicle within the abdomen, it is caused to shrink in size and the semeniferous tubules are reduced in diameter and only contain cells of the Sertoli type.

The temperature of the scrotum is found to be from 1 to 8° C. lower than that of the abdomen, which lower temperatures are necessary for normal spermatogenesis. The lower temperature of the scrotum is effected by virtue of its exposed position, lack of subcutaneous fat, and a thin, usually hairless skin, rich in sweat glands. The temperature is further regulated by the dartos muscle relaxing with an increase in temperature and thus removing the testes further from the body, and conversely contracting with a decrease in temperature.

In some species, notably among Cetacea and birds, spermatogenesis takes place at body temperature. In bison, spermatogenesis would seem to take place at a temperature nearer to that of the body than in domestic cattle. Thus, the testes of bison appear to be comparatively smaller than those of cattle, are kept tucked up close to the body cavity while the scrotum has a scaly skin with a covering of hair on the upper portion during winter. It is probable, therefore, that spermatogenesis in the bison takes place at higher temperatures as an adaptation against severe winter conditions that would cause injury to testes in a pendulous, unprotected scrotum of the domestic type.

The bison scrotal condition is partially dominant in the first-cross hybrids, while the one-fourth bison hybrids show some variation of this characteristic. It is, therefore, possible that the hybrid germinal epithelium fails to develop normally owing to the testes being kept at a higher temperature caused by a thick scrotal skin and proximity to the body. This observation is supported by the cryptorchid-like appearance of the semeniferous tubules of the half and one-fourth bison hybrids slaughtered. In the yak it is quite possible a similarly higher temperature condition exists within the scrotum, owing to the protection of the latter by long body hairs.

Sterility and Mortality Problem

The sterility of male hybrids and the mortality of cows and calves are very serious limiting factors in the attempt at establishing a self-breeding cattalo or bison hybrid herd. As previously stated, the cause of sterility in males seems to be due to temperature differences within the scrotums of cattle compared with bison (and yak) giving cryptorchid-like testes in the hybrids, although incompatibility of sex chromosomes is also suggested as a probable causal factor. Also, the mortality of cows and calves is shown to be much less where domestic sires rather than bison sires are used.

There is sufficient evidence to indicate that the first-cross hybrid bison males are 100 per cent sterile. Of the second-cross hybrid males, Boyd (4) found one out of 4 hybrid (one-fourth bison) males tested that was fertile, and Iwanoff

(14) reports fertility of this group. However, neither in the Goodnight nor Wainwright herd have any second-cross hybrid males proven to be fertile. The third-cross males appear to be usually fertile, although the Wainwright one-eighth bison was not. Sections from this male's testes, however, indicate some spermatogenesis. The third-cross males are obtained by different methods of crossing. Goodnight obtained them by crossing an Angus sire with three-fourths bison females. Boyd obtained Quinto Porto by crossing a bison sire with a one-fourth bison hybrid. There are not sufficient data to indicate any best system of mating for producing fertile males. However, owing to the reduced mortality of crosses involving domestic sires, it would seem the best policy to use them until fertile hybrid males are obtained, and then breed the hybrids *inter se*. The hybrid herd would tend to become established at about a one-fourth bison blood level or slightly lower, a level which is very satisfactory from the standpoint of conformation and probably of hides.

Segregation of infertile males would occur until the character of fertility has become fixed. For practical purposes the character of fertility in cattalo should be of the domestic rather than the bison type in order that cattalo-domestic crosses give fertile males.

Practical Considerations

That cattalo have distinctive commercial possibilities is apparent from the enthusiasm of those who have had anything to do with them. That it is a hazardous but feasible undertaking to produce a self-breeding cattalo herd has been demonstrated by both Goodnight and Boyd. Unfortunately, the Boyd herd was dispersed at a time when fertile males were being obtained, while the Goodnight herd had to be sacrificed largely on account of an epidemic of contagious abortion which spread from the cattle herd. In other herds, mortality, sterility, the time factor, difficulties of obtaining bison, the maintenance of segregation of animals and mating indifference seem to have disillusioned the hybridizers.

The objectives in developing a cattalo herd to meet Canadian requirements are slightly different from those which hybridizers sought in the United States. Thus in Texas, where the Goodnight herd was developed, the objective was to produce hardy, disease resistant animals that would thrive on parched, scanty pastures. Goodnight considered the hybrids resistant to Texas fever and black-leg, and that they would not drift in storms nor run from heel flies. Hybridizers in the mid-western States would have similar environmental conditions, except for more severe winter storms. In Canada, the objective of the Wainwright experiment is to develop cattalo for economical beef production in the northern sections of the Prairie Provinces. Disease problems, other than tuberculosis and contagious abortion, are of no consequence. Winters, however, are very severe, with widely fluctuating temperatures and deep, encrusted snows. Under such conditions cattalo would doubtless thrive much better than the domestic breeds and with less attention as to housing and feed. A problem of the rancher on the less fertile ranches is that of keeping up the body size. Cattalo bulls which would impart hybrid vigour would doubtless find favour under such conditions.

Since 1928 hybridization with yak, with the exception of a few hybrid females which were reserved, has been discontinued at Wainwright. The one-fourth yak hybrids make fair beef animals, but they have not proven to be especially hardy and, therefore, offer no special value, at least for the purpose of this experiment. In Asiatic countries the yak-domestic hybrids appear to have a definite place in economical meat production.

Summary

1. A brief outline of the experiences and results of bison-domestic hybridizers is given.
2. History, management, environment and results obtained from the Wainwright hybridization experiment with cattle, bison and yak are presented.
3. From the data obtained the following tentative formulae on the inherited characteristics in relation to domestic cattle are given: Bison bb, BsBs, brbr, SS, DD, ii, inin, hlhl, hh, VV; Yak: BB, bsbs, brbr, SS, dd, ii, inin, hlhl, hh, VV, gg, TT, nsns.

The symbols represent respectively black, black spotting, brindle, self, dilution, non-intensity, inguinal white, hair length, horns, voice, grey nose, tail and muzzle shape.

4. The conformation of bison-domestic hybrids tends to be intermediate with partial dominance of the domestic type. The yak confirmation tends to be partially dominant over both domestic and bison.
5. Other characteristics discussed are: wallowing, rising, hides, hybrid vigour, meat and body weights of hybrids and parents.
6. The bison X -domestic and their hybrid females have resulted in 19 male and 17 female live calves, 14 still births, 12 abortions and a mortality of 20 cows. The domestic sire X bison and hybrid females gave less mortality than the reverse cross. The cattle, bison, yak and their hybrid crosses gave 21 male and 18 female live calves, 6 still births, 7 abortions and a mortality of 3 cows.
7. No fertile bison-domestic hybrid males have been obtained in the Wainwright herd. The tested males include half, one-fourth and one-eighth bison hybrids. One yak-domestic fertile hybrid male was obtained. The experiment with yak was largely discontinued in 1928.
8. Morphological and histological evidence indicates a scrotal temperature difference between bison and cattle which suggests a causal factor in the sterility of hybrid males although incompatibility of sex chromosomes is also suggested as a cause.
9. Sterility, mortality and breeding problems in developing a cattalo herd, and the economic possibilities of cattalo are discussed.

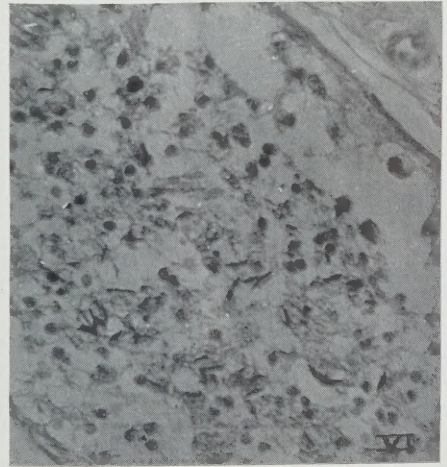
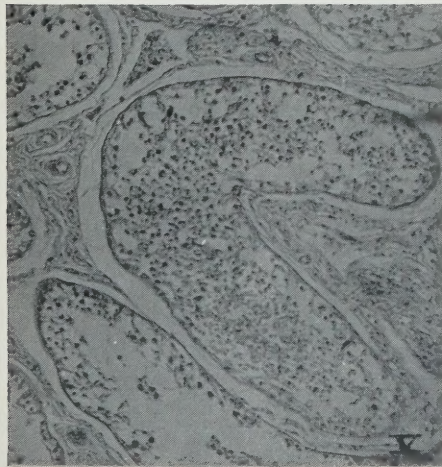
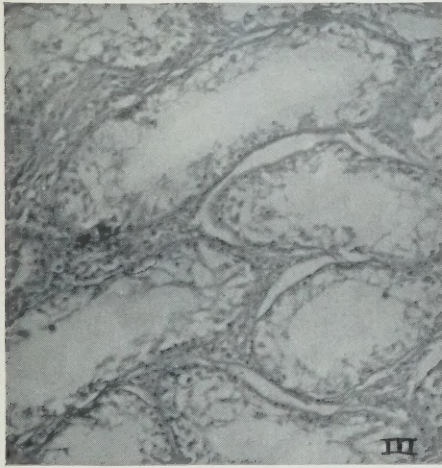
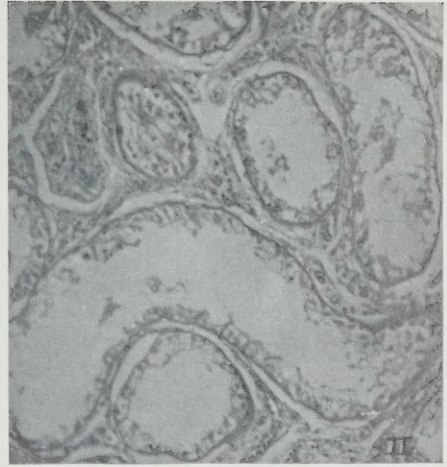
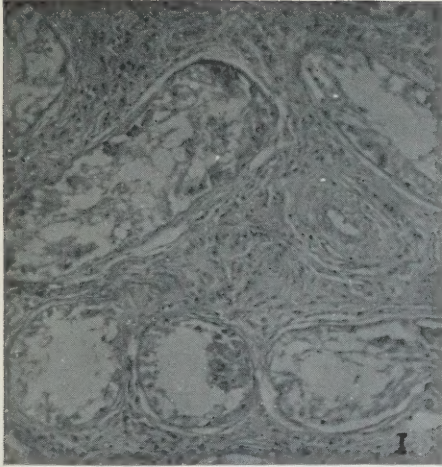
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PHOTOMICROGRAPHS OF SECTIONS OF BISON-DOMESTIC HYBRIDS' TESTES

Note absence of germinal epithelium and degenerative condition of the seminiferous tubules in figures 1 to 4. Magnification X 100.

- I. From a three-fourths domestic one-fourth bison hybrid. Age seven and a half years.
- II. From a three-fourths domestic one-fourth bison hybrid. Age six and a half years.
- III. From a half domestic half bison hybrid, (Domestic sire-bison dam). Age five and a half years.
- IV. From a half domestic half bison hybrid (Domestic sire-bison dam). Age two and a half years.
- V. From a seven-eighths domestic one-eighth bison hybrid. Age seven and a half years.
Note active mitosis and some spermatogenesis but absence of typical arrangement of germinal tissue.
- VI. High magnification (X 450) of part of the hooked tubule shown in figure V.



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